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Adaptive Performance: The Role of Knowledge Structure Development

by

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ABSTRACT

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The ability to successfully engage in adaptive performance is important due to the increasingly dynamic nature of work. The way individuals organize concepts within a performance domain (knowledge structures) has important implications for subsequent performance, including adaptive performance. Past literature has focused on the team knowledge structures and routine or overall performance. It is not evident whether changes in *individuals*' knowledge structures after an *adaptive* performance episode will enhance or impair performance. The current study investigated knowledge structure change and its relationship with individual differences and performance outcomes. The sample contained 185 individuals from a private southern university. There was no evidence of relationships between individual differences or performance outcomes and knowledge structure change. However, the current study contributed to the literature by measuring knowledge structures multiple times and across routine and adaptive performance episodes. Study implications and the potential use of knowledge structures in training design are also discussed.

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The nature of work is becoming increasingly complex and dynamic (Burke, Pierce, & Salas, 2006; Pulakos, Arad, Donovan, & Plamondon, 2000). The rising complexity of work places a larger emphasis on the cognitive skills of individuals (Kozlowski et al., 2001), while the dynamic nature of work requires individuals to adapt their knowledge and skills to novel situations. This shift towards complexity and change has important implications for selecting employees who are adaptable and training employees to be adaptable (Lang & Bliese, 2009) as well as the role of cognition in these employment-related functions. The importance of cognition in selection and training is highlighted by the prevalence of cognitive-related tests utilized in selection as well as the necessity of using cognitive outcomes in training (Kraiger, Ford, & Salas, 1993).

Given the importance of understanding the role of cognition in individuals' ability to effectively perform in adaptive performance situations, it is necessary to investigate the way in which cognitive-related constructs develop over different types of performance episodes and the way in which these constructs are affected by engaging in adaptive performance. Currently, the way knowledge structures develop over the course of multiple routine and adaptive performance episodes and the effect of performance on subsequent knowledge structure development is unknown. Although researchers have identified individual differences that are related to performance outcomes and knowledge structures (e.g., LePine, Colquitt, & Erez, 2000; Beier, Campbell, and Crook, 2010), less is known about the way in which individual differences contribute to the development of knowledge structures over the course of routine and adaptive performance episodes. In this study, I will attempt to answer the question: what contributes to an individual's capacity to maintain effective performance when presented with an unforeseen change in the performance environment? To answer this question, I will investigate the relationships among several critical individual differences and the development of knowledge structures after an adaptive performance episode, and the way in which the development of knowledge structures is related to adaptive performance and subsequent routine performance outcomes.

Adaptive Performance and Adaptability

Adaptive performance is required when an individual must perform effectively in a novel (Chen, Thomas, & Wallace, 2005) or changing task environment (LePine et al., 2000; Kozlowski et al., 2001; Chen et al., 2005) and is characterized by being responsive to variable job demands (Hesketh & Neal, 1999). Variable job demands include being placed in a new work team, being required to solve a poorly-defined problem, or having to use new technology. Adaptive performance builds on general domain knowledge, extending beyond the expertise that influences routine performance (e.g., performance in typical situations; Kozlowski & DeShon, 2004).

Adaptive performance has been characterized by “types” and by “dimensions.” Lang and Bliese (2009) introduced two types of adaptation: transition adaptation and reacquisition adaptation. Transition adaptation (a) occurs immediately after a task change, (b) is a flexible and instant reaction that minimizes decreases in performance, and (c) is measured relative to the prior performance episode and therefore takes into account the learning rate in the pre-change period. Reacquisition adaptation follows transition adaptation and is characterized by an individual’s speed in regaining their performance level. The defining aspects of reacquisition adaptation are (a) it refers to the recovery process following a performance loss after a task change, (b) it is a “systematic and analytical learning behavior needed to understand and learn the new challenges of the task" (Lang & Bliese, 2009, p. 415), and (c) it is measured as the learning rate after the task change accounting for the rate of skill acquisition before the change (Lang & Bliese, 2009).

In addition to type of adaptation, adaptive performance has also been characterized by dimensions. Pulakos et al. (2000) sought to systematically define and empirically investigate the underlying dimensions of adaptive performance and introduced an eight dimension taxonomy of adaptive performance: solving problems creatively; dealing with uncertain or unpredictable work situations; learning new tasks, technologies, and procedures; demonstrating interpersonal adaptability; demonstrating cultural adaptability; demonstrating physically oriented adaptability; handling work stress; and handling emergencies or crisis situations. Later work (Pulakos et al., 2002) tested these dimensions and confirmed the eight dimension taxonomy of adaptive performance proposed by Pulakos et al. (2000).

Individuals who perform well in novel or changing task environments are said to have high adaptability. Stable characteristics, such as cognitive ability or curiosity, have been endorsed as related to individuals' adaptability (e.g., Mumford, Baughman, Threlfall, Uhlman, & Costanza, 1993; Sternberg, 1997); however, there is still uncertainty concerning the specific individual differences that predict adaptability. It has been hypothesized that this ambiguity concerning which individual differences are predictive of adaptability results from a past focus on measures of adaptability that are based on a single type of individual difference (e.g., cognitive ability or personality), simplifying a construct that is likely influenced by multiple psychological phenomena (ability, motivation, and creativity), as well as a poorly conceptualized criterion for adaptability (LePine et al., 2000).

In addition to identifying individual differences that are related to adaptability, research also has demonstrated that the individual differences that predict performance in an adaptive environment are distinct from those that predict an individual's ability to perform a routine task. For example, LePine et al. (2000) found that decision-making performance prior to an unforeseen task change was related to performance after the change, but the relationship was only of moderate magnitude. Furthermore, the set of individual differences that predicted performance *before* the change was different than the individual differences that predicted performance *after* the change.

Differentiating Adaptive Performance from Other Types of Performance

In order to investigate and make predictions concerning adaptive performance, it is important to differentiate adaptive performance from other types of performance, particularly skill acquisition, basal task performance, and training transfer. Skill acquisition refers to the rate of change in performance across a specified time period and consists of three phases (Ackerman, 1988): cognitive stage; associative phase; and autonomous phase. The cognitive stage of skill acquisition occurs when an individual is presented with a new task. During this stage, individuals begin to develop strategies for approaching the task and are engaged in intensive cognitive processing. Through performing the task, individuals begin to transition into the second stage of skill acquisition, the associative phase (Ackerman, 1988). Individuals begin to perform the task with increasing speed and accuracy, having formulated the necessary strategies for task execution. The third and final stage of skill acquisition is referred to as the autonomous phase (Ackerman, 1988). In this stage, the individual can perform the task with speed and accuracy without devoting considerable cognitive resources towards executing the task. However, the rate of change characterized by the third stage of skill acquisition is not adaptive performance. The third phase of skill acquisition focuses on automating the task and skill maintenance. Adaptive performance, however, moves beyond mere skill maintenance through the generalization of skills and knowledge.

Basal task performance refers to “mean differences in the overall level of performance across a specified period of time” (Lang & Bliese, 2009, p. 414). On a linear skill acquisition model, basal task performance would be represented by the intercept; whereas, rate of skill acquisition would be represented by the slope. Basal task performance, like skill acquisition, has been demonstrated to represent a distinct performance domain from adaptive performance (Kozlowski et al., 2001).

Training plays an important role in contributing to individuals’ ability to engage in successful adaptive performance, elevating the importance of training transfer, a construct similar to adaptive performance. Training transfer has two facets: skill maintenance and generalization (Baldwin & Ford, 1988). Skill maintenance is the ability to reproduce learned skills from training in a new environment that is very similar or identical to the training setting (Goldstein & Ford, 2002), and generalization is the ability to adapt knowledge and skills from training to a more difficult and complex task environment (Ford, Smith, Weissbein, Gully, & Salas, 1998). Instead of conceptualizing training transfer as a reproduction of skills across environments, the generalization and adaptation of knowledge and skills from a training to a performance environment is gaining importance in practice (Kozlowski et al., 2001), particularly when the posttraining environment is more complex and dynamic (Ford et al., 1998; Kozlowski et al., 2001). The generalization facet of training transfer is not adaptive performance, but it does involve expertise in adapting (Smith, Ford, & Kozlowski, 1997). Thus, proficiency in the generalization aspect of training transfer will enable individuals to perform more effectively in adaptive performance situations.

Assessing Adaptability

The most frequently employed approach to measure individuals' adaptation to change is the task-change paradigm (e.g., LePine et al., 2000; Kozlowski et al., 2001; Chen et al., 2005). The task-change paradigm is an experimental design where participants are introduced to a novel and complex task and begin to acquire skill by learning and practicing the task. During the process of skill acquisition, an unforeseen task change occurs, requiring the individual to engage in adaptive performance (Chen et al., 2005). Most of the research that utilizes a task-change paradigm does not warn individuals of the change (e.g., LePine, 2003; LePine et al., 2000); however, other research has alerted individuals that a change will occur but keeps hidden the nature of the change (Kozlowski et al., 2001; Chen et al., 2005). Through changing an aspect of the task environment, complexity is increased (Marks, Zaccaro, & Mathieu, 2000; Chen et al., 2005; LePine et al., 2000), which parallels an adaptive performance situation in an occupational context (LePine, 2005). Research utilizing the task-change paradigm has been characterized by two important attributes: (a) task mastery is not required to introduce the unanticipated task change (Betsch, Haberstroh, Molter, & Glockner, 2004), and (b) there has been little agreement on how to best approach data analysis such that the measurement of individual adaptability is not contaminated by differences in skill acquisition and overall ability (Lang & Bliese, 2009).

Individual Differences and Adaptive Performance

In order to prepare individuals to perform effectively in novel environments, we must better understand the individual differences and the cognitive mechanisms that lead to successful adaptive performance by individuals after a training intervention. Identifying and understanding the relationships between individual differences and adaptive performance has implications for training design (Lang & Bliese, 2009). Thus, past research has sought to identify individual differences that are related to effective adaptive performance (e.g. Kozlowski et al., 2001; LePine et al., 2000; Lang & Bliese, 2009). The most common individual differences that have been investigated are personality traits, goal orientation, and general mental ability (GMA).

The two Big Five personality dimensions that are thought to have a theoretical basis for demonstrating a relationship with adaptive performance are conscientiousness and openness to experience. Individuals who are conscientious are described as self-disciplined, organized, and self-motivated. Conscientiousness has been found to demonstrate a positive relationship with a wide variety of job performance outcomes (Barrick & Mount, 1991). Yet, LePine et al. (2000) found a negative relationship between conscientiousness and post task change performance. Conscientiousness, however, has a motivational component as well as a dependability component. LePine (2003) attributed the negative conscientiousness-post task change performance relationship to the achievement facet of conscientiousness likely being related to adaptive performance, whereas the dependability facet likely was not.

The second personality trait thought to be related to adaptive performance is openness to experience. Individuals who describe themselves as open to experience are curious, open-minded, and original. Therefore, it is likely that these characteristics enable individuals to maintain performance levels when presented with a novel situation or task by exploring alternative strategies and being receptive to difference sources of feedback. Despite this, meta-analytic summaries have failed to support a relationship between openness to experience and overall performance (e.g., Barrick & Mount, 1991). However, Barrick and Mount (1991) found a relationship between openness to experience and ability to perform new tasks, and LePine et al. (2000) found a positive relationship between openness to experience and post task change performance.

In addition to conscientiousness and openness to experience, another individual difference that is thought to demonstrate a relationship with adaptive performance is goal orientation. Goal orientation influences an individual's approach to a situation (Button, Mathieu, & Zajac, 1996; Dweck, 1986). There are two types of goal orientation: learning goal orientation and performance goal orientation. Those who endorse a learning goal orientation believe that direct effort towards learning and exploration will lead to self-improvement. These individuals are resilient to errors and display an adaptive response to challenging or new situations. Performance goal orientation is typically conceptualized as a maladaptive response, and individuals who endorse a performance goal orientation tend to avoid new situations that will increase their likelihood of failure (Dweck, 1986; Nicholls, 1984). Kozlowski et al. (2001) found differential effects for goal orientation on adaptive performance, independent of individuals' cognitive ability: learning goal orientation demonstrated a significant relationship with performance adaptability, while the relationship between performance goal orientation and performance adaptability was not significant.

Finally, an additional individual difference that has been linked to adaptive performance in the extant literature is general mental ability (GMA). GMA represents the speed of information processing, and individuals who score high on measures of GMA tend to outperform individuals who score low on measures of GMA. Therefore, one may expect that individuals who produce high GMA scores would learn novel tasks more quickly than others. However, there have been divergent results for the relationship between GMA and adaptive performance. A number of studies have found that GMA has demonstrated a stronger relationship with tasks that are novel or complex compared to those that are routine or simple (e.g., Hunter & Hunter, 1984; Hunter & Schmidt, 1996; LePine et al., 2000; Pulakos et al., 2002), suggesting a positive relationship between GMA and adaptive performance. However, other studies have found a negative relationship between GMA and adaptive performance (e.g., Beilock & DeCare, 2007; Ricks, Turley-Ames, Wiley, 2007, Kane & Engle, 2000). Some mechanisms used to explain the negative relationship between GMA and adaptive performance are pressure to perform (Beilock & DeCare, 2007; Gimmig, Huguet, Caverni, & Cury, 2006), unexpected problems in familiar tasks (Ricks, Turley-Ames, Wiley, 2007), and dual-task performance (Rosen & Engle, 1997; Kane & Engle, 2000). Lang and Bliese (2009) attempted to reconcile these divergent findings by presenting two different types of adaptation, transition and reacquisition, which were found to demonstrate differential relationships with adaptive performance: GMA was negatively related to transition adaptation, while GMA did not demonstrate a relationship with reacquisition adaptation.

Training Outcomes and Adaptive Performance

A taxonomy of training outcomes was proposed by Kraiger et al. (1993), which supports a multidimensional view of learning and consists of three types of learning outcomes: knowledge (cognitive outcomes); skills (behavioral outcomes); and affect (affect and motivational outcomes). Research has investigated the relationship between these three learning outcomes and adaptive performance after training (Ford et al., 1998; Kozlowski et al., 2001) and found that the learning outcomes (declarative knowledge, self-efficacy, and skill acquisition) during training uniquely and positively predicted adaptive performance after training, even when learning strategies and individual differences (goal orientation and academic ability) were controlled. Thus, these learning outcomes will be important in predicting transfer of training and subsequent adaptive performance. Given the increasing complexity of the workplace, it is particularly essential to evaluate and understand these learning outcomes, and specifically, *cognitive* training outcomes.

Knowledge Structure

One specific cognitive training outcome is knowledge structure. The terms *knowledge structure* and *mental model* have been used to describe the way in which an individual organizes information. Knowledge structures enable individuals to describe, explain, and predict their environment (Rouse & Morris, 1986). An individual's knowledge structure is thought to represent a deeper understanding of the material compared to traditional knowledge assessments (e.g., declarative knowledge) and is the precondition of skilled performance in a given area (Kraiger et al. 1993). Knowledge structures have been viewed as information processing structures that influence the interpretation and translation of new information in individuals (Marks et al., 2000).

Knowledge structures can also distinguish expert performers from novices (Schvaneveldt et al., 1985). Ford and Kraiger (1995) argue that highly proficient individuals automatically know the correct way to respond, enabling these individuals to perform competently within different task contexts. As individuals gain competency in a task and accumulate more knowledge, the interconnectedness of the knowledge results in coherent groups of information (Glaser, 1990), which is reflected in the individual's knowledge structure.

The accuracy (similarity to an expert) of individuals' knowledge structures has been linked to important learning outcomes in both academic and training environments. Similarity to an expert knowledge structure was related to skill acquisition and predicted individuals' retention and transfer of training (Day, Arthur, & Gettman, 2001). In addition, the accuracy of trainees' knowledge structures fully mediated the relationship between computer skills training and declarative knowledge and task performance (Davis & Yi, 2004). In an academic setting, the accuracy of individuals' knowledge structures demonstrated a positive relationship with performance on course exams (e.g., Acton, Johnson, & Goldsmith, 1991; Goldsmith, Johnson, & Acton, 1994). Beier et al. (2010) also found that accuracy of knowledge structures predicted exam performance, accounting for approximately 16% of the variance in performance. In addition, Beier et al. (2010) investigated ability and non-ability predictors of knowledge structures and found that cognitive ability, conscientiousness, and mastery goal orientation demonstrated significant, positive relationships with knowledge structure accuracy.

Knowledge Structure and Adaptive Performance

Knowledge structures, as information-processing structures, play an important role in the interpretation and translation of novel information (Marks et al., 2000). The majority of past research has examined the relationship between knowledge structures and *overall* or *routine* performance and has been conducted at the team level (e.g. Marks et al., 2000; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Knowledge structures have been identified as “essential enablers” for the adaptive performance of a team (Resick et al., 2010); thus, studies (Marks et al., 2000; Resick et al., 2010) are beginning to emerge that investigate adaptive performance, rather than routine performance. These team studies are typically investigating knowledge structures representative of teamwork skills, rather than skills that would be necessary for individual-level performance (e.g., taskwork skills). Marks et al. (2000) examined teams’ adaptation to novel elements of a task environment by examining the effect of leader briefings and team-interaction training influence team members’ knowledge structures and the relationship of the knowledge structures to performance in routine and novel environments. The study changed an aspect of the task (the environment) in order to simulate an adaptive performance situation. The knowledge structures represented team-interaction knowledge about how to work together within a given performance domain and were compared on similarity (the extent to which individuals share a mental model) as well as accuracy (an accurate representation of the task environment). The study results indicated that team mental model similarity demonstrated a positive relationship with adaptive performance, indicating that teams that shared the same conceptualization of teamwork with one another performed better when adaptive performance was required.

A second study that examined the role of knowledge structure in adaptive performance of teams, Resick et al. (2010), investigated three different metrics for assessing the knowledge structure of teams as well as the predictive ability of knowledge structures for adaptive performance. The study found that knowledge structures, assessed by a structural networks approach, demonstrated predictive validity for adaptive performance.

Although a large portion of knowledge structure research has been conducted with teams, it is important to first fully understand the role of knowledge structures in facilitating effective adaptive performance at the individual level. However, few studies have investigated the role of knowledge structures in predicting adaptive performance at the individual level. One exception is Kozlowski et al. (2001), which investigated the relationships among various training learning outcomes, including knowledge structures, and adaptive performance. Kozlowski et al. (2001) found that knowledge structure predicted performance adaptability after controlling for declarative knowledge and previous performance.

Research is beginning to emerge concerning the role of knowledge structures in predicting adaptive performance; however, studies do not typically measure knowledge structures at multiple intervals (e.g., after training; a routine performance episode; and an adaptive performance episode). For example, Kozlowski et al. (2001) measured participants' knowledge structures at the end of training, and Resick et al. (2010) measured mental models after the fifth cycle of routine and adaptive performance but did not assess individuals' knowledge structures before and after different types of performance episodes (e.g. routine and adaptive). Therefore, it is still unclear how mental models change in relationship to an adaptive performance episode and whether this change is related to effective adaptive performance. However, one exception is Marks et al. (2000), which assessed teams' knowledge structure three times, allowing for comparisons among the knowledge structures. Marks et al. (2000) implemented interventions (leadership briefings and team interaction training) to develop knowledge structures for various performance environments and assessed participants' knowledge structures of a performance domain prior to performing in that domain. Marks et al. (2000) answered important questions concerning the way in which knowledge structures influence performance. The next logical question concerns the effect of performance on subsequent knowledge structure development, a question that remains largely unanswered in the literature. Therefore, it is important to investigate the way in which performing in different domains (e.g., adaptive and routine) affects the development of knowledge structures as well as its implications for subsequent performance by assessing knowledge structures after individuals engage in the various performance domains.

Knowledge Structure Flexibility

Based on their findings, Marks et al. (2000) identified mental model flexibility as a key characteristic of mental models, in that "teams are able to shift knowledge structures in accurate and similar ways" (p.982). The authors argued that qualitatively different mental models were needed for the different performance environments, although the underlying task and performance goals were the same. Enhanced leader briefings and team interaction training contributed to mental model flexibility in that participants were able to shift their knowledge structures more accurately before entering a novel environment. The authors cite *cognitive entrainment* as a description of the cognitive stability (inflexibility of knowledge structures) that leads to teams losing structure and the ability to scan and interpret their environment when confronted with a novel situation (Marks et al., 2000).

Although Marks et al. (2000) cites mental model flexibility as a key characteristic of mental models, it is unclear how a knowledge structure changes *after* a performance episode that requires adaptive performance or whether the flexibility of knowledge structures (a shift in knowledge structure) is important for individuals to be effective in an adaptive performance situation as well as the influence on subsequent performance episodes.

I will refer to knowledge structure flexibility as a change in an individual's organization of knowledge based on the demands of a performance environment. There are a number of knowledge structures characteristics that can serve as indicators of flexibility: number of links, coherency, and similarity. Number of links refers to the number of links between concepts in an individual's knowledge structure, and internal consistency (coherence) refers to the extent that the concepts are linked in a meaningful pattern (Goldsmith & Kraiger, 1996) and is a correlation between "direct relatedness rating and a set of derived indirect ratings" (Schuelke et al., 2009, p. 1077). When the direct relatedness ratings match indirect ratings, coherence is high (Stout, Salas, & Kraiger, 1997). Schuelke et al. (2009) found a small gain in pairing coherence and closeness of knowledge structures in the prediction of transfer (without controlling for baseline skill, GMA, and declarative knowledge). Knowledge structure similarity refers to the number of links that correspond between two knowledge structure networks.

Knowledge structure flexibility can manifest in various ways, each influencing performance. The current study will investigate two possible knowledge structure flexibility models of interest: the *shifting knowledge structure model* and the *integrating knowledge structure model*.

Shifting knowledge structure. Marks et al. (2001) discussed knowledge structure flexibility as individuals' ability to shift their knowledge structures more accurately before entering a novel environment. *The shifting knowledge structure* is similar to Marks et al.'s (2001) conceptualization of knowledge structure flexibility and refers to the ability of an individual to shift between knowledge structures, depending on the performance environment. In the shifting knowledge structure model, knowledge structures must qualitatively change in order to be successful for an adaptive performance episode. It is likely that the number of links will not decrease, and the coherence will not increase in a linear manner since these individuals are shifting between different knowledge structures, rather than refining a single structure.

Integrating knowledge structure. The integrating knowledge structure model refers to the ability of individuals to incorporate aspects of the performance environment into their knowledge structure, continuing to develop a more defined and comprehensive knowledge structure. In this model, different parts of the same knowledge structure will increase in importance, depending on the performance environment. Research has demonstrated that a difference between expert and novice mental models of structural systems is that experts tend to integrate the structural components in their knowledge structure, while novices' knowledge structures are representative of aspects that are static and perceptually available (Chi, Felovich, & Glaser, 1981). The knowledge structure coherency scores and number of links of these individuals will likely increase and decrease, respectively, in a linear manner as they refine their knowledge structures across performance episodes.

The Present Study

Knowledge structure serves as important intermediary between individual differences and performance. Individual differences likely affect the development and changes in knowledge structures, which in turn will affect performance outcomes. Thus, knowledge structures have been used as a training outcome and a predictor for training transfer to a novel environment. In this study, I will examine knowledge structure development over the course of routine and adaptive performance episodes and will assess whether critical individual differences predict knowledge structure development as well as whether knowledge structure change predicts routine and adaptive performance outcomes.

Due to the lack of empirical work that specifically focuses on the longitudinal trends of knowledge structure development and refinement in novel contexts, my initial goal is to document and describe the nature knowledge structure change when individuals are presented with routine and adaptive performance episodes:

Research Question 1: How does routine and adaptive performance affect the development of knowledge structures?

The first two hypotheses pertain to the way in which aspects of individuals' knowledge structure change after an adaptive performance episode.

Hypothesis 1a: Knowledge structure coherency after routine performance will predict knowledge structure coherency after adaptive performance.

Hypothesis 1b: Number of links after routine performance will predict the number of links after adaptive performance.

Individual differences, such as goal orientation, the Big Five personality traits, and general mental ability have been used to predict the adaptive performance of individuals. It is possible that these individual differences also can be used to predict knowledge structure change after an adaptive performance episode.

Research has documented that individuals who endorse openness to experience are described as curious and often seek out unconventional ideas. It is possible that these individuals will be more likely to incorporate novel aspects of an adaptive performance environment to further refine their knowledge structure.

Hypothesis 2a: The relationship in hypothesis 1a will be moderated by openness to experience.

Hypothesis 2b: The relationship in hypothesis 1b will be moderated by openness to experience.

Conscientiousness is a personality trait used to describe individuals who are organized and self-disciplined. It is possible that these individuals are more attentive to changes in their performance environment after an adaptive performance episode and will use these changes to further improve their knowledge structure.

Hypothesis 3a: The relationship in hypothesis 1a will be moderated by conscientiousness.

Hypothesis 3b: The relationship in hypothesis 1b will be moderated by conscientiousness.

Learning goal orientation is characterized by exploring, and errors and feedback are used to enhance learning. It is likely that individuals with a learning goal orientation will incorporate the novel aspects of their environment into their knowledge structure, which would be reflected in a more coherent knowledge structure after an adaptive performance episode. These individuals also will be more likely to use an adaptive performance episode to refine their knowledge structures; therefore, individuals with a learning goal orientation will be more likely to have fewer links in their knowledge structures after an adaptive performance episode.

Hypothesis 4a: The relationship in hypothesis 1a will be moderated by learning goal orientation.

Hypothesis 4b: The relationship in hypothesis 1b will be moderated by learning goal orientation.

Past research has found that individuals higher in cognitive ability developed knowledge structures that were more similar to the knowledge structure of an expert (Day et al., 2001). Given that coherency and smaller number of links are characteristic of an expert knowledge structure, the current study hypothesizes that those higher in cognitive ability will be able to use an adaptive performance episode to further refine their knowledge structure, which will be reflected in increased coherency and a decrease in number of links.

Hypothesis 5a: The relationship in hypothesis 1a will be moderated by general mental ability.

Hypothesis 5b: The relationship in hypothesis 1b will be moderated by general mental ability.

Adaptability refers to an individual's response to changes in their environment. Individuals high in adaptability respond successfully to these changes and are likely to be better equipped to incorporate the novel components of an adaptive performance episode into their knowledge structure.

Hypothesis 6a: The relationship in hypothesis 1a will be moderated by adaptability.

Hypothesis 6b: The relationship in hypothesis 1b will be moderated by adaptability.

Knowledge structure flexibility will have implications for subsequent performance episodes. Marks et al. (2001) cite knowledge structure flexibility as an important characteristic of mental models and found that qualitative change in teams' knowledge structures was related to higher performance across multiple performance episodes. The following hypotheses will be investigated to clarify the influence of multiple indicators of knowledge structure flexibility on different types of performance for *individuals.*

Given exposure to multiple routine and adaptive missions, I propose the following hypotheses:

Hypothesis 7a: After an individual has engaged in routine performance, an increase in knowledge structure coherency will be positively related to subsequent adaptive performance.

Hypothesis 7b: After an individual has engaged in routine performance, a decrease in number of links will be positively related to subsequent adaptive performance.

Hypothesis 7c: After an individual has engaged in routine performance, knowledge structure similarity to the individual's prior knowledge structure will be positively related to subsequent adaptive performance.

Hypothesis 8a: After an individual has engaged in adaptive performance, an increase in knowledge structure coherency after the adaptive performance episode will be related post-adaptive routine performance.

Hypothesis 8b: After an individual has engaged in adaptive performance, a decrease in number of links after the adaptive performance episode will be positively related post-adaptive routine performance.

Hypothesis 8c: After an individual has engaged in adaptive performance, knowledge structure similarity to the individual's prior knowledge structure will be related post-adaptive routine performance.

Method

Participants

Participants were students from a small, private southern university campus. 46 participants were paid $50 for their participation, and 139 participants received subject pool credit for their participation. A power analysis was conducted, and the sample size exceeds the number of participants needed (55) to ensure that all statistical tests have the necessary power to detect a medium effect (.15) effect with an alpha level of .05 (Erdfelder, Faul, & Buchner, 1996). There was no significant difference between the two groups on all variables of interest, with the exception of pre-adaptive performance knowledge structure coherency, $t(183) = -2.14$, $p = .03$, $d = .36$. The effect size (*Cohen's d*) for the difference between the paid and non-paid groups on pre-adaptive performance knowledge structure coherency is smaller than a medium effect (Cohen, 1988). The total sample contained 185 individuals (52.43% female), and the mean age was 19.18 (*SD* =1.20).

Measures

Performance task. To assess individual performance, participants operated a battle tank simulator, *Steel Beasts Pro PE ver.2.483* (eSim Games, 2009). *Steel Beasts Pro PE* uses tanks to simulate a combat environment. Participants, each with his/her own computer, used a keyboard, monitor, joystick, and mouse to operate the PC-based game.

Two missions were created to assess task performance: routine and adaptive. The routine mission required individuals to travel from the south end of the simulated environment to the north end (destination marked on their map) and destroy 10 enemy tanks while traveling to their destination. A map also was included with each mission (accessible before and during the mission) marking the general location the enemy tanks. The adaptive mission was identical to the routine mission, except for one critical difference, thus serving as the change in the task-change paradigm. Specifically, the adaptive mission moved the starting point to a new location, in the middle of the battle field, requiring a different strategy from the routine mission.

Individuals were allowed 15 minutes to complete each mission. A mission concluded when either the individual had achieved the mission objectives or when 15 minutes had passed. Mission-level performance was operationalized as number of enemy tanks destroyed by the individual during each mission. Individuals earned 1 point for each enemy tank destroyed, and the maximum possible number of tanks is 12.

Personality. Personality was assessed with the IPIP-NEO (Goldberg, 1999), a 50-item broad bandwidth personality measure. Participants were asked to rate each item in the way that most accurately describes themselves using a Likert-type scale, with a choice of five response options (1 = *very inaccurate,* 2 = *moderately inaccurate*, 3 = *neither inaccurate or accurate,* 4 = *moderately accurate*, 5 = *very accurate*). Each of the five factors of personality (extraversion, agreeableness, conscientiousness, emotional stability, and openness to experience) was represented by ten items. Participants' scores for each personality factor were calculated by summing their responses for the ten items that represent each factor. Individuals' scores for the two personality factors of openness to experience and conscientiousness were retained for analysis. The scores obtained from this measure demonstrated acceptable reliability: Cronbach's alpha was .85 for openness to experience and .87 for conscientiousness.

Goal orientation. Goal orientation was assessed with a 17-item measure, for which participants were asked to rate themselves on each item by indicating the extent to which they personally agreed with each statement. The scale items used a five-choice format, with response options of 1 = *strongly disagree*; 2 = *disagree*; 3 = *neither agree nor disagree*; 4 = *agree*; 5 = *strongly agree*. Items represented each of the three dimensions of goal orientation (VandeWalle, 1997): performance-approach goal orientation (e.g., my goal in this study is to get a better score at Steel Beasts than most of the other participants); performance-avoid goal orientation (e.g., I worry about getting low scores on Steel Beasts); and learning goal orientation (e.g., I want to learn as much as possible about Steel Beasts during this study). Participants' scores for each goal orientation dimension were calculated by summing their responses for items that represent each dimension. Scores obtained from this measure demonstrated adequate score reliability: .94, .86, and .88 for the goal orientation approach, learning, and avoid scales, respectively.

General Mental Ability. Cognitive ability was assessed with participants' total SAT score (math and verbal). SAT scores have been demonstrated to be an acceptable measure of *g* with a .86 correlation (corrected for nonlinearity) with the Armed Services Vocational Aptitude Battery and a .72 (corrected for range restriction) with Raven's Advanced Progressive Matrices (Frey & Detterman, 2004).

Adaptability. Adaptability was assessed with the I-ADAPT measure (Ployhart & Bliese, 2006), a 50-item measure that reflects the eight dimensions of adaptive performance identified by Pulakos et al. (2000). Participants were asked to indicate the extent each statement represented their preferences, styles, or habits at work by using a Likert-type scale that ranged from 1 = *strongly disagree* to 5 = *strongly agree*. Two subscales of adaptability, stress and uncertainty, were identified as most relevant to the characteristics needed to successfully perform in the current study's adaptive performance environment, and thus, participants' adaptability score are the average of the items from these two subscales. The scores demonstrated high reliability: Cronbach's alpha = .88.

Knowledge structures. Knowledge structures were measured five times: 1) after completion of training, 2) after the second routine performance episode, 3) after two more routine performance episodes, 4) after two adaptive performance episodes, and 5) after two more routine performance episodes. Knowledge structure was measured using a paper-pencil matrix containing ten domain concepts, which differs from other methods that are typically used (e.g., Target, Rate; see Appendix A). The initial pool of domain concepts contained 196 items, and four experts were asked to rate frequency of use and criticality to achieving the overall goal of the performance task for each item. The product of these ratings was calculated, and the twelve domain concepts, discarding those with overlap, were retained for inclusion in the knowledge structure assessment. The method typically used to measure knowledge structure asks participants to make *all* pairwise comparisons of domain concepts on a *computer*, which differs from the method employed in the current study, which asked participants to make all possible pairwise comparisons for *one half* of the *paper-pencil* matrix by judging how related domain concepts are to each other. I chose the paper-pencil elicitation method, rather than the Target method because Target does not allow participants to view all of their ratings simultaneously or modify ratings. Furthermore, the paper-pencil method allowed participants to change their ratings as they complete the assessment, something that is not possible using either the Target or Rate programs that are typically used in knowledge structure assessment.

The participants' ratings were entered into Pathfinder for analysis (Schvaneveldt, 1990; Schvaneveldt, Durso, & Dearholt,1989). Pathfinder is a software program that assesses knowledge structure and produces a graphical network display based on these ratings (Goldsmith & Kraiger, 1996). Pathfinder can also score knowledge structures, providing a quantitative assessment of an individual's knowledge structure (e.g., the coherency score, number of links, and knowledge structure similarity; Schuelke et al., 2009). Number of links refers to the number of links between concepts in an individual's knowledge structure. Coherence (internal consistency) is the extent that the concepts are linked in a meaningful pattern (Goldsmith & Kraiger, 1996) and is a correlation between "direct relatedness rating and a set of derived indirect ratings" (Schuelke et al., 2009, p. 1077). When the direct relatedness ratings match indirect ratings, coherence is high (Stout, Salas, & Kraiger, 1997). Finally, knowledge structure similarity refers to the number of links that correspond between two knowledge structure networks. Knowledge structure similarity ranges from 0 to 1 and is the total number of links in common divided by the total number of unique links.

Procedure

Each person was trained to use the simulator over the course of a 45-minute training through a series of tutorials that included both reading and brief hands-on practice. Following training, participants completed four sessions, each with 2 15-minute missions. The missions for sessions 1, 2, and 4 were routine, and the missions for session 3 were adaptive. For a detailed description of the study protocol, please see Figure 1.

Study Part	Scheduled Activities

0	Consent Form
	Payment Agreement*
	Individual Difference Measures
	    Personality
	    Goal Orientation
	    I-Adapt Measure
	    Demographics
	Steel Beasts Training
	Knowledge Structure (KS) 0

1	Routine Performance (Mission 1) Routine Performance (M2) **KS 1**
2	Routine Performance (M3) Routine Performance (M4) **KS 2**
3	Adaptive Performance (M5) Adaptive Performance (M6) **KS 3**
4	Routine Performance (M7) Routine Performance (M8) **KS 4**
	Debrief Form – Attachment G W9 Form – Attachment 3* Payment Form – Attachment 4*

Note. Additional measures for the paid participants are indicated by an asterisk.

Figure 1. Study Protocol.

Results

Variable means, standard deviations, and correlations for all measured variables are presented in Table 1.

Table 1

Intercorrelations, Means, and Standard Deviations of All Study Variables

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. Openness to Experience	3.78	0.56	.85																					
2. Conscientiousness	3.54	0.72	.22	.87																				
3. LGO	2.97	0.85	.09	.13	.86																			
4. GMA	1469	90.67	-.05	-.02	.22	-																		
5. Adaptability	3.61	0.44	.35	.04	.13	.07	.88																	
6. KS 0 Coherency	0.39	0.23	.18	-.08	.00	.06	.03	-																
7. KS 1 Coherency	0.41	0.24	.03	-.01	-.07	.01	.07	.38	-															
8. KS 2 Coherency	0.47	0.23	-.01	.03	.01	-.06	.04	.32	.46	-														
9. KS 3 Coherency	0.41	0.24	.09	.14	-.09	.04	-.03	.27	.46	.52	-													
10. KS 4 Coherency	0.44	0.25	.16	.09	-.01	-.15	-.08	.43	.48	.48	.63	-												
11. KS 0 Links	20.27	5.71	.26	.13	.13	-.02	.37	.04	-.05	.06	.02	-.09	-											
12. KS 1 Links	22.89	7.42	.16	.00	.16	-.00	.26	.11	.05	.12	-.01	.03	.63	-										
13. KS 2 Links	23.94	8.93	.17	.04	.15	-.05	.21	.10	.04	.03	.01	.05	.50	.64	-									
14. KS 3 Links	24.45	9.29	.12	.02	.08	-.02	.23	.17	.05	.06	.03	.09	.46	.62	.77	-								
15. KS 4 Links	24.18	9.06	.17	.01	.07	-.02	.28	.18	.08	.12	.04	.10	.45	.59	.73	.81	-							
16. Similarity 1	0.40	0.13	.20	.06	.04	-.07	.16	.16	.21	.22	.31	.15	.46	.39	.30	.26	.26	-						
17. Similarity 2	0.45	0.15	.14	.06	.08	-.01	.09	.29	.34	.26	.22	.24	.33	.53	.37	.35	.37	.53	-					
18. Similarity 3	0.47	0.16	.10	.00	.07	.04	.17	.18	.15	.11	.19	.13	.37	.51	.61	.60	.59	.43	.57	-				
19. Similarity 4	0.48	0.17	.05	-.01	.05	.07	.11	.22	.20	.19	.26	.22	.27	.43	.52	.61	.60	.48	.50	.71	-			
20. Session 1 Performance	2.97	1.44	.01	-.02	.08	.13	.08	.06	.04	.13	.06	.16	-.05	-.06	-.05	-.06	-.05	-.00	.02	.01	.07	-		
21. Session 2 Performance	3.63	1.83	.03	.13	.11	.01	.10	.10	.17	.20	.14	.21	.10	.10	.08	.07	.04	.08	.13	.12	.10	.55	-	
22. Session 3 Performance	4.80	2.43	.03	.00	.13	.10	.24	.19	.12	.11	.11	.10	.10	.07	.07	.01	.03	.05	-.01	.03	.03	.42	.58	-
23. Session 4 Performance	4.47	2.04	.09	-.05	.13	.09	.21	.16	.13	.11	.10	.11	.10	.15	.11	.06	.08	.10	.06	.13	.11	.48	.54	.65

Note. N = 185 except GMA , N = 110. Cronbach's Alpha appears along the diagonal when available. LGO = learning goal orientation. GMA = general mental ability. KS = knowledge structure. Similarity 1 = post training and post routine performance KS similarity. Similarity 2 = post routine performance and post routine performance KS similarity. Similarity 3 = pre and post adaptive performance KS similarity. Similarity 4 = post adaptive performance and post adaptive routine performance KS similarity. For all relationships except those with GMA, correlations above .12 or below -.12 are significant, $p < .05$, two-tailed. For relationships with GMA, correlations above .16 or below -.16 are significant, $p < .05$, two-tailed.

Knowledge Structure Change

Research question 1 attempted to answer the question: how does routine and adaptive performance affect the development knowledge structures? The mean was calculated for two knowledge structure characteristics, coherency and number of links, for each time that a knowledge structure was measured (see Figures 3 and 4).

Knowledge structure coherency scores increased across routine performance episodes but decreased after an adaptive performance episode. A repeated measures ANOVA determined that knowledge structure coherency differed significantly across performance episodes, $F(4, 736) = 5.43$, $p < .001$, and there was evidence of a quadratic trend, $F(1, 184) = 4.25$, $p = .04$. The change in coherency score from after routine performance to after engaging in adaptive performance was significant, $F(1, 184) = 12.21$, $p = .001$; however, the effect size for the difference was small ($d = -0.25$; Cohen, 1988). After engaging in a routine performance episode, the coherency scores then increased; however, the coherency score remained slightly lower than the pre-adaptive performance coherency scores.

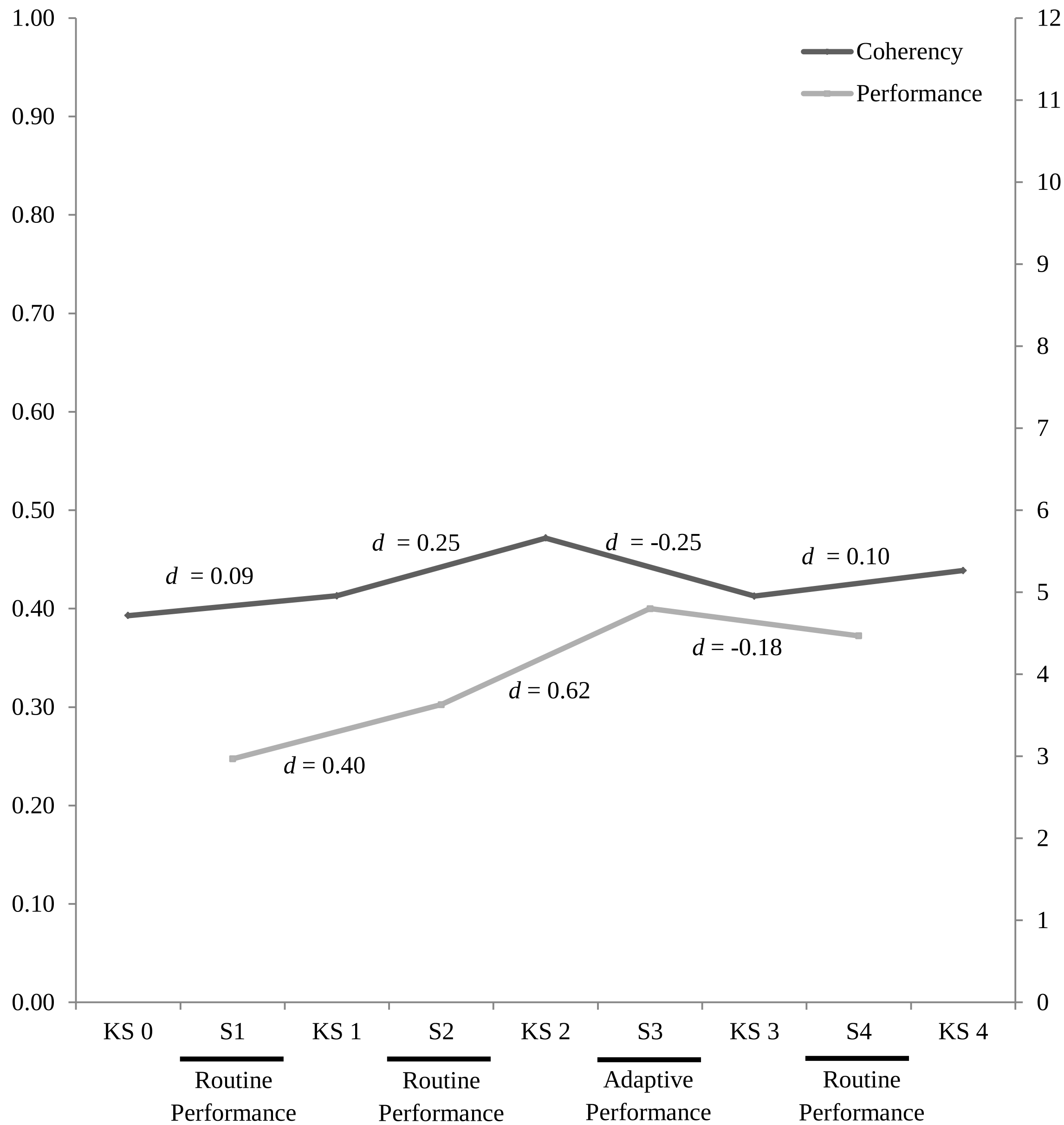

Figure 2. Knowledge structure coherency scores across performance episodes. *d* values represents the standardized mean difference (time 1 was subtracted from time 2, so a positive difference represents an increase from time 1 to time 2). KS = knowledge structure assessment. S1 – S4 = session 1 – session 4.

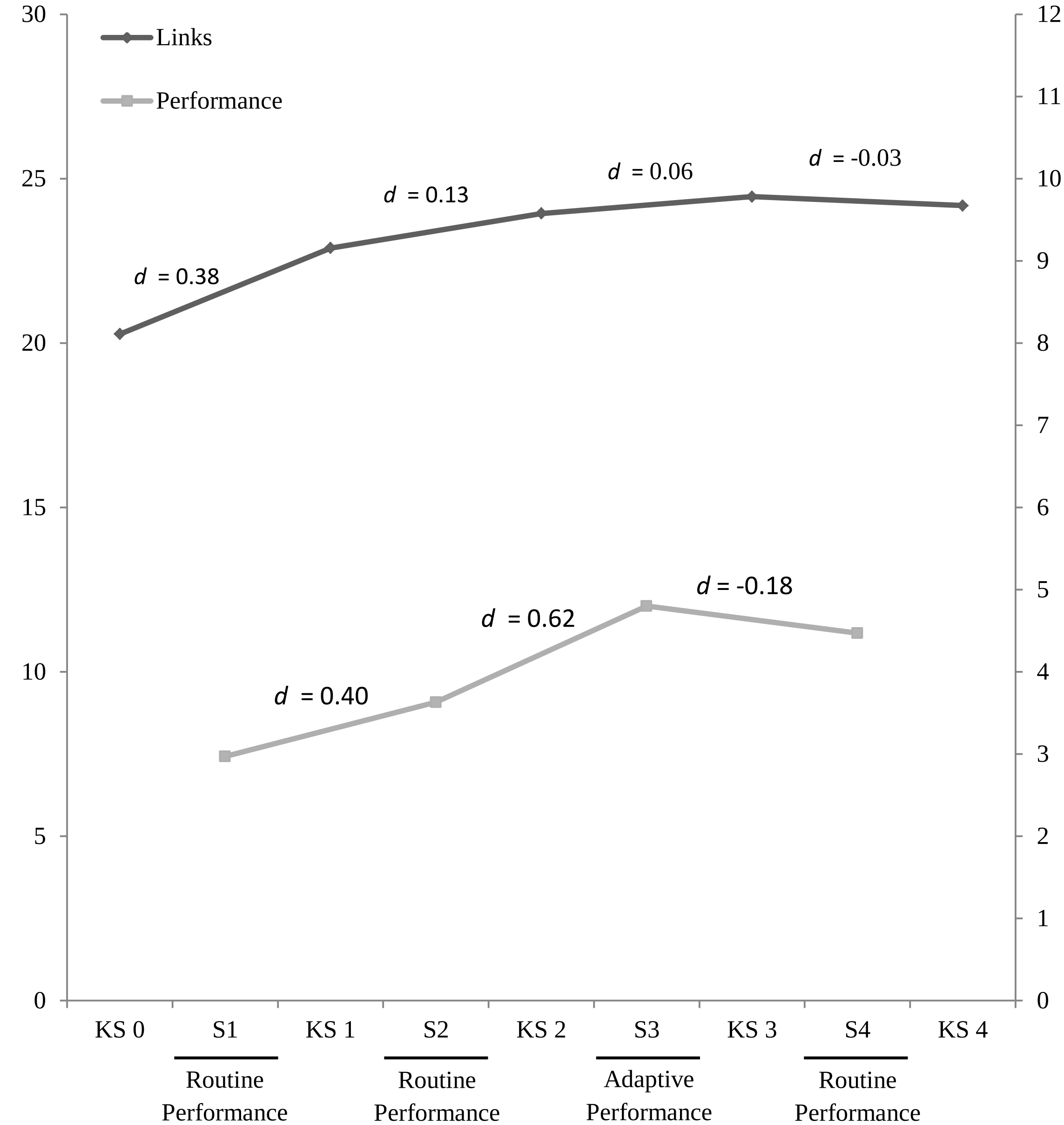

Figure 3. Knowledge structure number of links across performance episodes. *d* values represents the standardized mean difference (time 1 was subtracted from time 2, so a positive difference represents an increase from time 1 to time 2). KS = knowledge structure assessment. S1 – S4 = session 1 – session 4.

Knowledge structure number of links appeared to increase across routine performance episodes and this increase remained after engaging in an adaptive performance episode. The number of links then slightly decreased once the participants returned to a routine performance episode. A repeated measures ANOVA determined that knowledge structure number of links differed significantly across performance episodes, $F(4, 736) = 21.23$, $p < .001$, and there was evidence of a quadratic trend, $F(1, 184) = 24.65$, $p < .001$.

In order to evaluate all study hypotheses, regression analyses were conducted. All data was screened for the appropriate statistical assumptions and all assumptions were met. For the regression analyses, all independent variables were mean centered prior to calculating the interaction term. Tables 1-18 display the unstandardized regression coefficients (*B*) and their standard error (*SE B*), *R*, R^2, adjusted R^2, and the change in R^2 for the prediction of all study hypotheses.

Hypothesis 1 predicted that knowledge structure characteristics, a) coherency and b) number of links, after routine performance would predict knowledge structure characteristics after adaptive performance. To test hypothesis 1a and 1b, I conducted regression analyses with a DV of knowledge structure coherency following adaptive performance and a DV of number of links following adaptive performance, respectively. For 1a, I entered knowledge structure coherency after routine performance as the IV, $R^2 = .27$, $F(1, 183) = 68.80$, $p < .001$, and for 1b I entered number of links after routine performance as the IV, $R^2 = .59$, $F(1, 183) = 262.62$, $p < .001$. Hypotheses 1a and 1b were supported, suggesting that knowledge structure characteristics, coherency and number of links, prior to an adaptive performance episode predicted these knowledge structure characteristics after an adaptive performance episode.

Table 2

Regression of Post-adaptive Performance Knowledge Structure Coherency and Links on Pre-adaptive Performance Knowledge Structure Coherency and Links

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2
KS 2 Coherency	0.54*	0.07	.52	.27	.27
KS 2 Links	0.80*	0.05	.77	.59	.59

Note. $N = 185$. $^*p < .05$.

The next five hypotheses predicted that the relationships in hypotheses 1 would be moderated by the following individual differences: openness to experience, conscientiousness, learning goal orientation, cognitive ability, and adaptability.

Individual Differences and Knowledge Structure

To test hypotheses 2a and 2b (the relationships in hypotheses 1 would be moderated by openness to experience), I conducted two moderated regression analysis with a) knowledge structure coherency following adaptive performance as the DV and b) number of links following adaptive performance as the DV. The first step of the regression analyses was the same regression analysis used to test hypothesis 1. The addition of openness to experience did not result in a significant change in R^2 for knowledge structure coherency, $F(1, 182) = 1.40$, $p = .16$, nor for the number of links, $F(1, 181) = -0.30$, $p = .77$. In the third step, I added the product of the first and second IVs as the third IV (interaction term). The interaction term was not significant for coherency, $F(1, 181) = 0.21$, $p = .84$, nor number of links, $F(1, 181) = 0.17$, $p = .86$; thus, hypothesis 2a and 2b were not supported. Openness to experience did not predict change in knowledge structure characteristics after an adaptive performance episode.

Table 3

Hierarchical Regression of Post-adaptive Performance Knowledge Structure Coherency on Pre-adaptive Performance Knowledge Structure Coherency and Openness to Experience

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.52	.27	.27	.27*
KS 2 Coherency	0.54*	0.07				
Step 2			.53	.28	.27	.01
KS 2 Coherency	0.54*	0.07				
Openness to Experience	0.04	0.03				
Step 3			.53	.28	.27	.00
KS 2 Coherency	0.54*	0.43				
Openness to Experience	0.04	0.03				
KS 2 Coherency X Openness	0.02	0.11				

Note. $N = 185$. *$p < .05$.

Table 4

Hierarchical Regression of Post-adaptive Performance Knowledge Structure Links on Pre-adaptive Performance Knowledge Structure Links and Openness to Experience

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.77	.59	.59	.59*
KS 2 Links	0.80*	0.05				
Step 2			.77	.59	.59	.00
KS 2 Links	0.80*	0.05				
Openness to Experience	-0.23	0.80				
Step 3			.77	.59	.58	.00
KS 2 Links	0.80*	0.05				
Openness to Experience	-0.25	0.81				
KS 2 Links X Openness to Experience	0.01	0.08				

Note. $N = 185$. $^*p < .05$.

Hypothesis 3a and 3b predicted that the relationships in hypotheses 1 would be moderated by conscientiousness. To test this hypothesis, I conducted a moderated regression analysis with a) knowledge structure coherency and b) number of links following adaptive performance as the DVs. In the second step, I entered conscientiousness as the second IV. For knowledge structure coherency, the addition of conscientiousness to the model resulted in a significant change in R^2, $F(1, 182) = 2.02$, $p = .04$, suggesting that conscientiousness is a significant predictor of knowledge coherency after adaptive performance. However, the change in R^2 was very minimal, .02. For number of links, the addition of conscientiousness did not result in a significant change in R^2, $F(1, 182) = -0.15$, $p = .88$. In the third step, I added the product of the first and second IVs as the third IV (interaction term). The interaction was not significant for knowledge structure coherency, $F(1, 181) = -0.55$, $p = .59$, indicating that conscientious is a main effect and does not interact with knowledge structure coherency to predict post-adaptive performance coherency. The interaction for number of links also was not significant, $F(1, 181) = 0.94$, $p = .35$. Thus, hypothesis 3a and 3b was not supported, suggesting that conscientiousness does not predict change in knowledge structure characteristics after an adaptive performance episode.

Table 5
Hierarchical Regression of Post-adaptive Performance Knowledge Structure Coherency on Pre-adaptive Performance Knowledge Structure Coherency and Conscientiousness

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.52	.27	.27	.27*
KS 2 Coherency	0.54*	0.07				
Step 2			.54	.29	.28	.02*
KS 2 Coherency	0.54*	0.07				
Conscientiousness	0.04*	0.02				
Step 3			.54	.29	.28	.00
KS 2 Coherency	0.55*	0.07				
Conscientiousness	0.04*	0.02				
KS 2 Coherency X Conscientiousness	-0.06	0.11				

Note. $N = 185$. $*p < .05$.

Table 6
Hierarchical Regression of Post-adaptive Performance Knowledge Structure Links on Pre-adaptive Performance Knowledge Structure Links and Conscientiousness

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.77	.59	.59	.59*
KS 2 Links	0.80*	0.05				
Step 2			.77	.59	.59	.00
KS 2 Links	0.80*	0.05				
Conscientiousness	-0.09	0.61				
Step 3			.77	.59	.59	.00
KS 2 Links	0.80*	0.05				
Conscientiousness	-0.03	0.62				
KS 2 Links X Conscientiousness	0.07	0.08				

Note. $N = 185$. $*p < .05$.

To test hypothesis 4a and 4b (the relationships in hypotheses 1 would be moderated by learning goal orientation), I conducted two moderated regression analysis with a) knowledge structure coherency and b) knowledge structure number of links following adaptive performance as the DVs. In the second step, I entered learning goal orientation as the second IV, which was not significant for coherency ($F(1, 182) = -1.56$, $p = .12$) nor number of links (, $F[1, 182] = -0.72$, $p = .47$). In the third step, I added the product of the first and second IVs as the third IV. The introduction of the interaction term was not significant for coherency , $F(1, 182) = 1.32$, $p = .19$, or number of links, $F(1, 181) = 1.52$, $p = .13$. Hypothesis 4a and 4b was not supported, suggesting that learning goal orientation does not predict change in knowledge structure characteristics after an adaptive performance episode.

Table 7

Hierarchical Regression of Post-adaptive Performance Knowledge Structure Coherency on Pre-adaptive Performance Knowledge Structure Coherency and Learning Goal Orientation

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.52	.27	.27	.27*
KS 2 Coherency	0.54*	0.07				
Step 2			.53	.28	.28	.01
KS 2 Coherency	0.55*	0.07				
Learning Goal Orientation	-0.03	0.02				
Step 3			.24	.29	.28	.01
KS 2 Coherency	0.55*	0.07				
Learning Goal Orientation	-0.03	0.02				
KS 2 Coherency X Learning Goal Orientation	0.11	0.08				

Note. $N = 185$. $^*p < .05$.

Table 8

Hierarchical Regression of Post-adaptive Performance Knowledge Structure Links on Pre-adaptive Performance Knowledge Structure Links and Learning Goal Orientation

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.77	.59	.59	.59*
KS 2 Links	0.80*	0.05				
Step 2			.77	.59	.59	.00
KS 2 Links	0.80*	0.05				
Learning Goal Orientation	-0.38	0.52				
Step 3			.77	.60	.60	.01
KS 2 Links	0.78*	0.05				
Learning Goal Orientation	-0.39	0.52				
KS 2 Links X Learning Goal Orientation	0.08	0.06				

Note. $N = 185$. $^*p < .05$.

To test hypothesis 5a and 5b, the relationships in hypotheses 1 would be moderated by general mental ability, I conducted two moderated regression analyses with

a) knowledge structure coherency and b) number of links following adaptive performance as the DV. In the second step, I entered GMA as the second IV. The addition of GMA did result in a significant increase in R^2 for knowledge structure coherency, $F(1, 107) = 0.85$, $p = .40$, nor number of links, $F(1, 107) = 0.18$, $p = .86$. In the third step, I added the product of the first and second IVs as the third IV (interaction term). The interaction was not significant for knowledge structure coherency, $F(1, 106) = -0.48$, $p = .63$, nor number of links, ($F(1, 106) = -0.74$, $p = .46$. Hypothesis 5a and 5b were not supported.

Table 9
Hierarchical Regression of Post-adaptive Performance Knowledge Structure Coherency on Pre-adaptive Performance Knowledge Structure Coherence and General Mental Ability

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.56	.32	.31	.32*
KS 2 Coherency	0.59*	0.08				
Step 2			.57	.32	.31	.01
KS 2 Coherency	0.59*	0.08				
General Mental Ability	0.00	0.00				
Step 3			.57	.32	.30	.00
KS 2 Coherency	0.60*	0.09				
General Mental Ability	0.00	0.00				
KS 2 Coherency X General Mental Ability	0.00	0.00				

Note. $N = 185$. $*p < .05$

Table 10
Hierarchical Regression of Post-adaptive Performance Knowledge Structure Links on Pre-adaptive Performance Knowledge Structure Links and General Mental Ability

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.76	.58	.57	.58*
KS 2 Links	0.80*	0.07				
Step 2						
KS 2 Links	0.80*	0.07	.76	.58	.57	.00
General Mental Ability	0.00	0.01				
Step 3			.76	.58	.57	.00
KS 2 Links	0.79*	0.07				
General Mental Ability	0.00	0.00				
KS 2 Links X General Mental Ability	0.00	0.00				

Note. $N = 185$. $*p < .05$.

Hypothesis 6a and 6b predicted that the relationships in hypotheses 1 would be moderated by adaptability. In order to test this hypothesis, I conducted two moderated regression analyses with knowledge structure coherency and number of links following adaptive performance as the DVs. In the second step, I entered adaptability as the second IV. For both coherency, $F(1, 182) = -0.59$, $p = .55$, and number of links, $F(1, 182) = .36$, $p = .72$, the addition of adaptability to the model was not significant,. In the third step, I added the product of the first and second IVs as the third IV (interaction term), and the introduction of the interaction term was not significant for coherency ($F(1, 181) = 0.86$, $p = .39$) or number of links ($F(1, 181) = 1.14$, $p = .26$). Hypotheses 6a and 6b were not supported.

Table 11

Hierarchical Regression of Post-adaptive Performance Knowledge Structure Coherency on Pre-adaptive Performance Knowledge Structure Coherency and Adaptability

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.52	.27	.27	.27*
KS 2 Coherency	0.54*	0.07				
Step 2			.53	.28	.27	.00
KS 2 Coherency	0.55*	0.07				
Adaptability	-0.02	0.03				
Step 3			.53	.28	.27	.00
KS 2 Coherency	0.55*	0.07				
Adaptability	-0.02	0.03				
KS 2 Coherency X Adaptability	0.02	0.09				

Note. $N = 185$. $*p < .05$.

Table 12

Hierarchical Regression of Post-adaptive Performance Knowledge Structure Links on Pre-adaptive Performance Knowledge Structure Links and Adaptability

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.77	.59	.59	.59*
KS 2 Links	0.80*	0.05				
Step 2			.77	.60	.59	.01
KS 2 Links	0.78*	0.05				
Adaptability	1.12	0.73				
Step 3			.77	.60	.59	.00
KS 2 Links	0.77*	0.05				
Adaptability	0.86	0.76				
KS 2 Links X Adaptability	0.09	0.07				

Note. N = 185. *p < .05.

The next set of hypotheses pertains to the way in which characteristics of knowledge structures (coherence, number of links, and similarity) predict individuals' adaptive and post-adaptive routine performance.

Knowledge Structure and Performance Outcomes

Hypothesis 7a predicted that after an individual has engaged in routine performance, an increase in knowledge structure coherence would be positively related to subsequent adaptive performance. I tested hypothesis 7a through a moderated regression analysis with adaptive performance as the DV. In the first step, I entered knowledge structure coherency after routine performance as the IV, R^2= .01, F(1, 183) = 2.17, p = .14. In the second step, knowledge structure coherency after adaptive performance was entered as the second IV, F(1, 182) = 0.86, p = .39. Finally, in the third step, I added the product of the first and second IVs as the third IV (interaction term). The introduction of the interaction term was not significant, F(1, 181) = -1.27, p = .21. Hypothesis 7a was not supported.

Table 13
Hierarchical Regression of Adaptive Performance on Pre-adaptive Performance Knowledge Structure Coherency and Post-adaptive Performance Knowledge Structure Coherency

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.11	.01	.01	.01
KS 2 Coherency	1.14	0.78				
Step 2			.13	.02	.01	.00
KS 2 Coherency	0.73	0.91				
KS 3 Coherency	0.75	0.87				
Step 3			.16	.02	.01	.01
KS 2 Coherency	0.39	0.95				
KS 3 Coherency	0.74	0.87				
KS 2 Coherency X KS 3 Coherency	-3.90	3.07				

Note. N = 185. *p < .05.

Hypothesis 7b stated that after an individual has engaged in routine performance, a decrease in number of links would be positively related to subsequent adaptive performance. I tested hypothesis 7b through a moderated regression analysis with adaptive performance as the DV. In the first step, I entered number of links after routine performance as the first IV, R^2= .01, F(1, 183) = 1.01, p = .32. In the second step, knowledge structure links after adaptive performance was entered as the second IV, F(1, 182) = -1.04, p = .30. Finally, in the third step, I added the product of the first and second IVs as the third IV (interaction term). The interaction between number of links after routine performance and number of links after adaptive performance was not significant, F(1, 181) = -0.13, p = .90. Hypothesis 7b was not supported.

Table 14
Hierarchical Regression of Adaptive Performance on Pre-adaptive Performance Knowledge Structure Links and Post-adaptive Performance Knowledge Structure Links

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.07	.01	.00	.01
KS 2 Links	0.02	0.02				
Step 2			.11	.01	.00	.01
KS 2 Links	0.05	0.03				
KS 3 Links	-0.03	0.03				
Step 3			.11	.01	-.01	.00
KS 2 Links	0.05	0.03				
KS 3 Links	-0.03	0.03				
KS 2 Links X KS 3 Links	0.00	0.00				

Note. $N = 185$. $^*p < .05$.

Hypothesis 7c stated that after an individual has engaged in routine performance, knowledge structure similarity to the individual's prior knowledge structure would be positively related to subsequent adaptive performance. I tested hypothesis 7c through a regression analysis with adaptive performance as the DV and knowledge structure similarity between knowledge structures before and after the adaptive performance mission as the IV. The results were not significant, $R^2 = .00$, $F(1, 183) = .17$, $p = .68$. Thus, hypothesis 7c was not supported.

Table 15
Regression of Adaptive Performance on Similarity between Pre-adaptive Performance Knowledge Structure and Post-adaptive Performance Knowledge Structure

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2
Knowledge Structure Similarity	0.46	1.12	.03	.00	-.01

Note. $N = 185$. $^*p < .05$.

Hypothesis 8a predicted that after an individual has engaged in adaptive performance, an increase in knowledge structure coherency after the adaptive performance episode would be related post-adaptive routine performance. I tested hypothesis 8a through a moderated regression analysis with post-adaptive routine performance as the DV. In the first step, I entered knowledge structure coherency after adaptive performance as the IV, R^2 = .02, F(1, 183) = 2.34, p = .13. In the second step, knowledge structure coherency after post-adaptive routine performance was entered as the second IV, F(1, 182) = 0.66, p = .51. Finally, in the third step, I added the product of the first and second IVs as the third IV (interaction term). The introduction of the interaction term was not significant, F(1, 181) = 0.17, p = .87. Hypothesis 8a was not supported.

Table 16
Hierarchical Regression of Post-adaptive Routine Performance on Post-adaptive Performance Knowledge Structure Coherency and Post-adaptive Routine Performance Knowledge Structure Coherency

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.10	.01	.01	.01
KS 3 Coherency	0.85	0.63				
Step 2			.11	.01	.00	.00
KS 3 Coherency	0.48	0.81				
KS 4 Coherency	0.57	0.76				
Step 3			.12	.01	-.00	.00
KS 3 Coherency	0.52	0.82				
KS 4 Coherency	0.63	0.78				
KS 3 Coherency X KS 4 Coherency	0.71	2.07				

Note. N = 185. $*p < .05$.

Hypothesis 8b stated that after an individual has engaged in adaptive performance, a decrease in number of links after the adaptive performance episode would be positively related post-adaptive routine performance. I tested hypothesis 8b through a moderated regression analysis with post-adaptive routine performance as the DV. In the first step, I entered number of links after adaptive performance as the IV, R^2 = .00, F(1, 183) = 0.69, p = .40. In the second step, number of links after post-adaptive routine performance was entered as the second IV, F(1, 182) = 0.78, p = .44. Finally, in the third step, I added the product of the first and second IVs as the third IV (interaction term. The interaction was not significant, F(1, 181) = 0.46, p = .64. Hypothesis 8b was not supported.

Table 17
Hierarchical Regression of Post-adaptive Routine Performance on Post-adaptive Performance Knowledge Structure Links and Post-adaptive Routine Performance Knowledge Structure Links

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2	ΔR^2
Step 1			.06	.00	-.00	.00
KS 3 Links	0.01	0.02				
Step 2			.08	.01	-.00	.00
KS 3 Links	-0.00	0.03				
KS 4 Links	0.02	0.03				
Step 3			.09	.01	-.01	.00
KS 3 Links	-0.01	0.03				
KS 4 Links	0.00	0.03				
KS 3 Links X KS 4 Links	0.00	0.00				

Note. N = 185. *$p < .05$.

Hypothesis 8c proposed that after an individual has engaged in adaptive performance, knowledge structure similarity to the individual's prior knowledge structure would be related post-adaptive routine performance. I tested hypothesis 8c through regression analysis with post-adaptive routine performance as the DV and knowledge structure similarity between knowledge structures before and after the post-adaptive routine performance mission as the IV. The results were not significant, R^2 = .01, F(1, 183) = 2.09, p = .15. Hypothesis 8c was not supported, suggesting that knowledge structure similarity was not related to post-adaptive routine performance.

Table 18
Regression of Post-adaptive Routine Performance on Similarity between Post-adaptive Performance Knowledge Structure and Post-adaptive Routine Performance Knowledge Structure

Models and variables	*B*	*SE B*	*R*	R^2	Adjusted R^2
Knowledge Structure Similarity	1.26	0.87	.11	.01	.01

Note. N = 185. *$p < .001$.

Discussion

The purpose of the current study was to examine knowledge structure development during complex task acquisition. The study focused on critical individual differences that have been empirically linked to knowledge structure development or adaptive performance. In addition, the current study explored knowledge structure development across routine and adaptive performance episodes. Specifically, I investigated the relationship between individual differences and knowledge structure change after an adaptive performance episode and the effect of knowledge structure change on adaptive performance and subsequent routine performance.

Knowledge Structure Change

Knowledge structure change across performance episodes was empirically assessed to determine whether engaging in routine and adaptive performance episodes affected the development of knowledge structures. Knowledge structure coherency scores increased across routine performance episodes. This is consistent with the notion that higher knowledge structure coherency reflects a more expert knowledge structure. However, the coherency scores decreased after an adaptive performance episode. This suggests that engaging in adaptive performance influenced individuals to alter the relationships amongst domain concepts in an inconsistent manner. Although there was a significant decrease in knowledge structure coherency after engaging in adaptive performance, the effect size for the difference was small. After engaging in a post-adaptive routine performance episode, the coherency scores then increased but remained slightly lower than the pre-adaptive performance coherency scores. It seems individuals are able to more logically organize performance domain concepts after reverting back to routine performance. However, the illogical manner in which the performance domain concepts were organized after adaptive performance appears to have a somewhat lasting effect: coherency is lower after post-adaptive routine performance, compared to coherency after routine performance prior to the unforeseen task change.

The number of knowledge structure links appeared to increase across routine performance episodes, and this increase remained after engaging in an adaptive performance episode. The number of links then slightly decreased once the participants returned to a routine performance episode. This suggests that as individuals continue to perform the task, they are reporting more relationships amongst performance domain concepts. The increasing number of links across performance episodes is not characteristic of an expert knowledge structure (Bradley, Paul, & Seeman, 2006).

The pattern for knowledge structure coherency across performance episodes was consistent with expectations; however, the pattern for knowledge structure number of links was not. On the one hand, individuals appear to be developing greater expertise in the task, reflected by increasing coherency. However, the increasing number of links suggests that individuals are also developing knowledge structures that are consistent with empirical conceptualizations of novice knowledge structures. In addition to the general increase in coherency and number of links, participants' performance also continued to increase across performance episodes until a slight decrease in post-adaptive routine performance. Thus, it seems that individuals are in fact developing proficiency and expertise. This is inconsistent with the knowledge structure being more similar to a novice knowledge structure.

The unexpected finding for the increasing number of links could be attributed to the performance domain concepts that were included in the knowledge structure assessment. In developing the knowledge structure, I purposefully retained domain concepts that were most relevant to achieving successful performance. Thus, it is possible that for the knowledge structure used in this study, greater number of links might actually reflect an expert knowledge structure because the domain concepts are all highly related. It also could be argued that having to engage in an adaptive performance episode and a post-adaptive routine performance episode influenced individuals to have a deeper understanding of the performance environment. This could have enabled individuals to develop expertise, which was reflected in a decrease in knowledge structure number of links after the post-adaptive performance routine episode. More performance episodes and knowledge structure assessments are needed to determine whether the number of links continue to decrease.

Knowledge Structure Change and Adaptive Performance

Hypothesis 1 focused specifically on the effect of adaptive performance on knowledge structure change, which predicted that knowledge structure coherency and links prior to adaptive performance would predict knowledge structure coherency and links after an adaptive performance episode. Although participants experienced an unforeseen change in their environment, the characteristics of their knowledge structure remained relatively stable. These findings suggest that participants develop knowledge structures and continue to refine them throughout task acquisition, as opposed to generating new knowledge structures for routine versus adaptive situations. This point is addressed in further detail in the shifting versus integrating section below.

Individual Differences and Knowledge Structure

The second hypothesis investigated the relationship between individual differences and knowledge structure change after engaging in an adaptive performance episode. Five individual differences were examined: openness to experience, conscientiousness, learning goal orientation, general mental ability, and adaptability.

Overall, none of the individual differences assessed in this study predicted change in knowledge structure coherency or number of links.

Although individuals can have simultaneous but different performance and learning goals, it is possible that individuals focused on a performance goal throughout the missions. A performance goal was given to the participants at the beginning of each mission; whereas, a learning goal was not given to participants. Thus, individuals' performance goals might have overshadowed their learning goals, accounting for the lack of findings for learning goal orientation and knowledge structure development.

For general mental ability and conscientiousness, it is possible that the lack of findings is due to the measurement method of these variables. It could be beneficial to measure GMA with an objective ability measure, such as Raven's Advanced Progressive Matrices, rather than relying on self-report SAT scores. In addition, given LePine et al.'s (2000) divergent findings for conscientiousness at the facet-level, it is possible that results could have differed if conscientiousness was measured at the facet level.

It is surprising that adaptability did not predict knowledge structure development after individuals were presented with an unforeseen task change. However, adaptability was significantly related to adaptive performance; whereas, the knowledge structure assessment after adaptive performance was not related to adaptive performance. Thus, it is possible that adaptability is a proximal predictor of adaptive performance, and knowledge structure does not act as an intermediary between these two constructs.

Although it is possible that the above individual differences did not influence the development of knowledge structures, it is more likely that the knowledge structure measurement method is not nuanced enough to detect small but important changes in knowledge structures after performing in different environments. Furthermore, past literature that has observed relationships among the specified individual differences and knowledge structures have not measured knowledge structures as many times as knowledge structures were assessed in the current study. It is possible that individuals experienced fatigue by the multiple knowledge structure assessment, and thus, did not pay careful attention or responded with less accuracy to the subsequent knowledge structure assessments.

Despite individual differences not predicting change in knowledge structure after adaptive performance, openness to experience predicted coherency and number of links of the knowledge structure measured directly after training. Openness to Experience has been referred to as Intellect or Curiosity and can be conceptualized as a self-report intelligence measure, particularly for crystallized intelligence (Ackerman & Goff, 1994; Goff & Ackerman, 1992). These characteristics embodied by openness to experience are important to individuals' ability to logically relate performance domain concepts after engaging in self-guided training.

Knowledge Structure and Performance Outcomes

The third set of hypotheses examined the relationship between knowledge structure characteristics, coherency, number of links, and similarity, and performance outcomes. Overall, knowledge structures appeared to be unrelated to routine or adaptive performance outcomes. Interestingly, knowledge structure coherency measured directly after training did not predict routine performance prior to adaptive performance (e.g., a proximal performance outcome) but did predict adaptive performance outcomes and post-adaptive routine performance outcomes (e.g., distal performance outcomes). This highlights the important of training, in that those individuals who were able to coherently relate domain concepts after training (versus those who were not) were able to perform more effectively when presented with an unforeseen task change. This finding is surprising in that the post-training knowledge structure that predicted adaptive performance was developed prior to actually performing the trained task. In addition, the knowledge structures, measured by coherency, developed after performing the trained task were not related to adaptive performance outcomes. It is possible that training gives individuals the tools to develop a knowledge structure that is more logically organized and a better conceptualization of the performance environment. This knowledge structure developed through training enabled individuals to maintain effective performance when presented with an unforeseen task change, compared to the knowledge structures that individuals developed while performing the task. Thus, the results imply that individuals' knowledge structures are unrelated to initial performance outcomes after training. Given that the knowledge structure assessment after training predicted distal performance outcomes, it appears that knowledge structures developed prior to hands-on training represent an outcome of training that is not present in immediate post-training performance. The cognitive understanding of the task, as reflected by the knowledge structure, is an important training outcome. Training developed by using expert knowledge structures could further enhance the relationship between the knowledge structure developed after training and important performance outcomes. This notion is consistent with Smith-Jentsch, Cannon-Bowers, Tannenbaum, and Salas (2008), who developed a team training protocol based on expert knowledge structures. Their results indicated that those who participated in the knowledge structure-based training had superior cognitive, teamwork, and performance outcomes, compared to those who participated in a more traditional training method.

Shifting versus Integrating

The current study measured knowledge structures multiple times across routine and adaptive performance episodes, providing insight into knowledge structure flexibility. The refinement of a knowledge structure across performance episodes is indicative of the integrating knowledge structure model. This is in contrast to a shifting knowledge structure, which would have been characterized by the presence of two qualitatively different knowledge structures for routine and adaptive performance.

The knowledge structure measured after the adaptive performance episode appeared to be more similar to the pre-adaptive performance knowledge structure and the post-adaptive routine performance knowledge structure, compared to the similarity between these two knowledge structures (both measured after a routine performance episode). The similarity between pre-adaptive performance and post-adaptive performance knowledge structure is significantly different than the similarity between pre-adaptive performance and post-adaptive routine performance knowledge structure ($t(184) = 3.62$, $p < .001$, $d = .20$). These results support the integrating model.

It appears that there is greater similarity between knowledge structures that are developed in close proximity temporally, regardless of the type of performance environment the individual engaged in prior to knowledge structure assessment, compared to knowledge structures that are developed after performing in analogous performance environments. This suggests that individuals begin with a knowledge structure after training and continue to revise that knowledge structure across both routine and adaptive performance episodes. If the development of knowledge structures followed the shifting model, one would expect greater knowledge structure similarity between the knowledge structures that were developed after engaging in similar performance environments. One would also expect that the knowledge structure developed after performing in a routine environment would not be similar to the knowledge structure developed after performing in an adaptive environment. The current study's finding that individuals continue to refine their knowledge structures, even after a task change, is counter to the results of Marks et al. (2000). Marks et al. (2000) cite mental model flexibility as a key characteristic of mental models and argued that qualitatively different mental models were needed for the different performance environments.

Limitations and Future Directions

There are several important limitations of the current study to consider and each may serve as a potential avenue for future research. The current study was conducted in a laboratory setting, using a tank-simulator game and a 5-hour protocol. Although an artificial laboratory setting may call into question the generalizability of results, a large discrepancy between the results of field versus laboratory research has not been observed (e.g., Anderson, Lindsay, & Bushman, 1999; Dipboye & Flanagan, 1979). Furthermore, the task used in this study was a complex task, requiring psychomotor, information processing, and cognitive skills, and was comparable to tasks performed in a work environment. This is also evidenced by the performance task being used by the United States Department of Defense as well as other global military operations (Villado & Arthur, 2013). However, the 5-hour training protocol used in this study is not analogous to length of training that would be observed in operational settings. The knowledge and performance outcomes across routine and adaptive performance in the current study are likely most representative of the initial phase of skill acquisition. Therefore, the results of the current study might be overestimating the relationships with adaptive performance. In order to ensure that study setting (laboratory versus field) does not moderate the relationships under investigation, it would be beneficial to replicate the study in an applied setting with longer duration training, particularly due to the relative lack of knowledge structure studies that have been conducted in a field setting.

The generalizability of the results of this study could be limited by the performance domain concepts that were selected to be included in the knowledge structure assessment. The domain concepts were chosen by having four experts rate frequency of use and criticality to achieving the overall goal of the performance task for a pool of items. The product of these ratings was calculated, and the twelve domain concepts were retained for inclusion in the knowledge structure assessment. Thus, only the domain concepts that were rated as the most essential to effective performance on the task were included in the knowledge structure assessment. It is possible that the results could differ if the relationships between other performance-related concepts were included in the list of terms rated by participants. Additional research should be conducted to determine whether the specific content of the knowledge structure is critical to the development of coherency, number of links, and similarity.

Conclusion

The purpose of the current study was to examine knowledge structure development over the course of routine and adaptive performance episodes and to assess whether individual differences predicted knowledge structure development and whether knowledge structure change predicted performance outcomes. Thus, the current study contributed to the literature by measuring knowledge structures multiple times and across routine and adaptive performance episodes.

Knowledge structure development may be more nuanced than portrayed in the extant literature. A clear and comprehensive understanding of knowledge structures and the development of knowledge structure characteristics (e.g., coherency, conceptual links) may only come from longitudinal assessment of knowledge structures. Furthermore, the relationship between individual differences and knowledge structures is also illusive. Although previous research has identified relationships between various individual differences and knowledge structures, none were observed in the current study. The relationship between immediate post-training knowledge structures and distal outcomes suggest that knowledge structures may be suitable measures of training effectiveness and support the notion that knowledge structures may serve as means to structure training. Finally, the results of this study suggest that individuals develop knowledge structures, and then subsequently refine those knowledge structures as they encounter new information and experiences. This is in contrast to the prevalent view that individuals develop, maintain, and vacillate between qualitatively different knowledge structures for various tasks and task environments.

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Appendix A

Please fill out the *bottom* half of the matrix below by indicating the extent to which all possible pairs of terms are related. Use the scale below and mark your rating in each box. For example, for the box marked with a “b” in the upper right-hand corner, you will be comparing the relatedness of *locating enemies* to *destroying enemy tanks* while playing Steel Beasts. Note: you will only be rating pairs for the bottom half part of the matrix. Please begin by comparing the relatedness of *daylight* to *aiming* in the box marked with an “a” in the upper right-hand corner.

1 2 3 4 5 6 7 8 9

Not at all related	Somewhat related	Moderately related	Very related	Extremely related

RID: ____

	Aiming	Daylight	Destroying enemy Tanks	Driving	Interpreting/ understanding the Map	Lasing the target	Locating enemies	Maintaining Situational Awareness	Shooting Quickly	Starting Location	Thermal Vision	Using correct role or view
1. Aiming	--											
2. Daylight	a	--										
3. Destroying enemy tanks			--									
4. Driving				--								
5. Interpreting/understanding the map					--							
6. Lasing the target						--						
7. Locating enemies			b				--					
8 Maintaining situational awareness								--				
9. Shooting quickly									--			
10. Starting location										--		
11. Thermal vision											--	
12. Using the correct role or view												--